

## Advanced Water Purification System For In Situ Resource Utilization

Completed Technology Project (2012 - 2013)



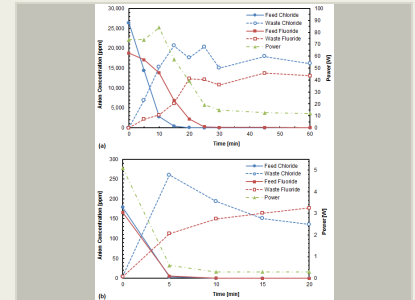
## Project Introduction

A main goal in the field of In Situ Resource Utilization (ISRU) is to develop technologies that produce oxygen from regolith to provide consumables to an extraterrestrial outpost. The processes developed reduce metal oxides in the regolith to produce water, which is then electrolyzed to produce oxygen. Hydrochloric and hydrofluoric acids are byproducts of the reduction processes, which must be removed to meet electrolysis purity standards. We previously characterized Nafion, a highly water selective polymeric proton-exchange membrane, as a filtration material to recover pure water from the contaminated solution. While the membranes successfully removed both acid contaminants, the removal efficiency of and water flow rate through the membranes were not sufficient to produce large volumes of electrolysis-grade water.

Prior to electrolysis, the water generated as an intermediate product must be treated to remove absorbed hydrochloric and hydrofluoric acids, byproducts derived from trace amounts of fluoride and chloride present in lunar regolith. In terrestrial applications, removal of chloride and fluoride from water is a relatively trivial process due to the availability of consumable adsorbents, or by utilizing other processes that require frequent regeneration. None of these processes are applicable in the lunar environment, however, where resources are scarce.

We previously studied Nafion, a commercially-available sulfonated tetrafluoroethylene polymer membrane, as an ISRU filtration material because it can continuously facilitate water transport and acid rejection without the need for replacement or regeneration. While Nafion showed promise as a filtration membrane, it was unable to remove sufficient quantities of contaminants, particularly fluoride, and would require very large membrane contact areas to generate appreciable quantities of clean water. Electrodialysis was chosen as an alternative water purification process for the present study, due to its extensive industrial pedigree and demonstrated ability to rapidly produce a clean water supply and concentrated waste brine.

Electrodialysis uses the principle of ion exchange. An electrodialysis stack contains alternating cation and anion exchange membranes between two electrodes, with fluid-containing channels between each. Initially contaminated feed (diluent) and initially clean waste (concentrate) solutions are passed through every other chamber as direct current is applied across the electrodes. Anionic contaminants in the diluent solution diffuse across the anion exchange membrane toward the anode (positively charged electrode), while cationic contaminants diffuse across the cation exchange membrane toward the cathode (negatively charged electrode). The ionic species become trapped in the concentrate solution, as the current directs anions toward cation exchange membranes through which they cannot diffuse, and vice-versa.



Contaminant concentration and power consumption profiles of the electrodialysis process.

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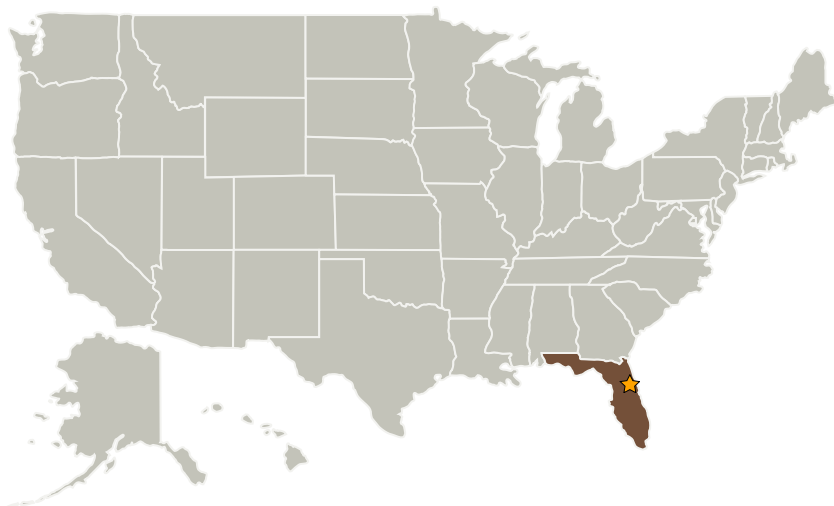
When dissolved in water, HCl and HF dissociate into their individual ionic species, i.e.  $H^+$ ,  $Cl^-$  and  $F^-$ . As a strong acid, HCl fully dissociates into its respective ions, while HF, a weak acid, only partially dissociates in an equilibrium process. It is therefore expected that HCl will rapidly and nearly completely diffuse from the diluent to the concentrate stream, while HF will diffuse into the concentrate stream more slowly, as the gradual removal of fluoride ions will allow more HF to dissociate and be removed from the diluent stream. It is also expected that as the ion concentration in the concentrate stream increases, osmotic pressure will drive water from the diluent to the concentrate stream over time, reducing the yield of clean water. As a result, experiments focused on optimizing both the quantity of chloride and fluoride ions removed from the diluent stream, and the rapidity of ion transfer.

### Anticipated Benefits

Electrodialysis has shown significant promise as the primary separation technique in ISRU water purification processes. The success of this technology will reduce the cost of operating and maintaining In Situ Resource Utilization (ISRU) systems, enabling long-term deep-space missions.

Electrodialysis was chosen as an alternative water purification process for this study, due to its extensive industrial pedigree and demonstrated ability to rapidly produce a clean water supply and concentrated waste brine. Potential customers for this technology may include ISRU Environmental Control and Life Support System (ECLSS) Space Power Systems

### Primary U.S. Work Locations and Key Partners



## Organizational Responsibility

### Responsible Mission Directorate:

Mission Support Directorate (MSD)

### Lead Center / Facility:

Kennedy Space Center (KSC)

### Responsible Program:

Center Independent Research & Development: KSC IRAD

## Project Management

### Program Manager:

Barbara L Brown

### Project Manager:

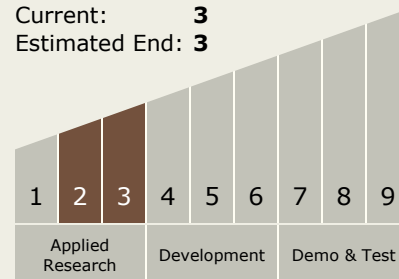
Nancy P Zeitlin

### Principal Investigator:

Stephen M Anthony

## Technology Maturity (TRL)

Start: 2  
Current: 3  
Estimated End: 3



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Organizations Performing Work	Role	Type	Location
★ Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
QinetiQ North America(QNA)	Supporting Organization	Industry	

## Primary U.S. Work Locations

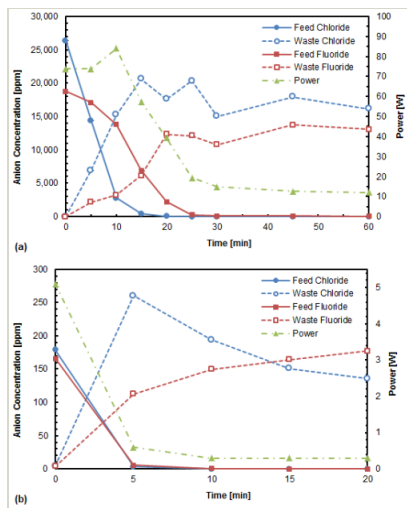
Florida

## Technology Areas

## Primary:

- TX07 Exploration Destination Systems
  - TX07.1 In-Situ Resource Utilization
    - TX07.1.3 Resource Processing for Production of Mission Consumables

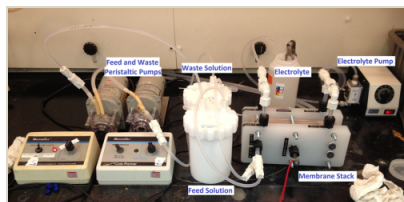
## Images



### Contaminant Concentration and Power Consumption Profiles

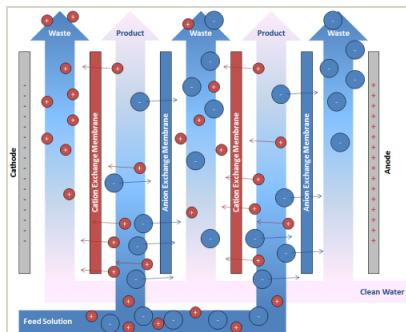
Contaminant concentration and power consumption profiles of the electrodesorption process.

(<https://techport.nasa.gov/image/2724>)



### Experimental Apparatus Used for Testing

Image of the experimental apparatus used to test the chloride and fluoride removal capabilities of the electrodesorption stack  
(<https://techport.nasa.gov/image/2723>)



## Schematic representation of the electrodialysis process

Schematic representation of the electrodialysis process

(<https://techport.nasa.gov/image/2722>)

## Links

Advanced Water Purification System for In Situ Resource Utilization

(<http://arc.aiaa.org/doi/pdfplus/10.2514/6.2013-5516>)

Contaminant Removal from Oxygen Production Systems for In Situ Resource Utilization

(<http://arc.aiaa.org/doi/pdfplus/10.2514/6.2012-5167>)